PLANT ASSOCIATIONS OF CASTLE CRAGS STATE PARK, SHASTA COUNTY, CALIFORNIA

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ABSTRACT

Vegetation types in Castle Crags State Park were classified using TWINSPAN into 8 series and 15 associations from 237 plots. The series, in decreasing order of abundance, were *Pseudotsuga menziesii, Quercus kelloggii, Alnus rhombifolia, Quercus chrysolepis, Ceanothus cuneatus, Bromus tectorum, Quercus garryana, and Juncus patens*. In addition, 2 types occurring in chronically disturbed habitats (powerline corridor and mowed meadow) were described. Each vegetation type was further described using physiography, soil characteristics, species diversity, tree density by height class, and basal area of tree species. Successional interpretations were made for plant associations.

INTRODUCTION

Castle Crags State Park has several important botanical and ecological roles: a) it serves as a landscape bridge and corridor across the Sacramento River between the southern Cascades and the Klamath Mountains; b) it is host to the rare *Ivisia longibracteata*; and c) it preserves low-elevation montane forest, shrub, riparian, and herbaceous communities. Adjacent lands along the Sacramento River corridor are heavily disturbed from logging, mining, development, and construction and maintenance of transportation routes. Plant associations in this ecologically diverse and vital park have not been adequately classified and described. In this paper we present a classification and description of the park's existing plant associations, ascribe their distribution to physiographic or soil characteristics, provide data for the future management of these communities, and assess the successional potential of the forests.

The park is recovering from a series of disturbances dating from the late nineteenth and early twentieth centuries (Beat and Gut 1981). Mining, logging, and wildfires consumed nearly all of the old-growth forest, leaving behind early successional communities that were apparently characterized by sprouting hardwoods and shrubs, shrub seedlings, early seral herbaceous species, and occasional surviving conifers. Conifer seedlings and some late seral shrub and herbaceous species were undoubtedly present in these early seral communities.

Today, after approximately 125 years of succession, the plant communities in Castle Crags State Park are relatively well defined.

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Much of the park is dominated by Douglas-fir and mixed conifer forest with meadows and shrublands situated on alluvial, granitic, or serpentinitic parent materials in Castle Creek Valley. Interspersed within the conifer forest are stands of California black oak.

Methods

Study Area

Castle Crags State Park encompasses 1681 ha both east and west of the Sacramento River in the Klamath Mountains Province, California (approximately 41°9′N, 122°20′W). Elevations range from approximately 640 m to 1220 m. Slopes typically exceed 40% and have soils derived from alluvium, serpentine, granitic rock, and greenstone (Mallory and Powell 1978). The Crags lying to the northwest of the state park are what remains of a granitic pluton that has been extensively eroded and glaciated.

The McCloud weather station, situated 17 km to the northeast, receives an average of 130 cm precipitation per year. Mean high temperatures are 8°C in winter and 30°C in summer. Mean low temperatures are −7°C in winter and 8.5°C in summer (National Climatic Data Center 1990).

Forested communities conform to the Society of American Foresters cover types of Pacific ponderosa pine—Douglas-fir, California black oak, and the Sierra Nevada mixed conifer (Eyre 1980).

Study Site Selection

We used 1:12,000 color stereo aerial photography in conjunction with a U.S.G.S. orthophoto of the Dunsmuir Quadrangle to identify areas (polygons) with apparently homogeneous vegetation composition and structure. Two hundred and thirty polygons were delimited. Of these we sampled all polygons that appeared to have unique structural or species composition characteristics. Forty-eight polygons were selected for ground sampling; the remaining polygons were indistinguishable from those selected for sampling. We established approximately 5 plots per selected polygon for a total of 237 plots.

Field Measurements

Plots were subjectively placed and centrally replicated to best characterize vegetation in each polygon (Mueller-Dombois and Ellenberg 1974). No ecotone plots were established. Forested plots were 0.1 ha in area, shrub-dominated plots were 0.05 ha, and herb-dominated plots 0.01 ha. Vascular plant cover was ocularly estimated to the nearest 5% for canopy trees, 1% for small trees and shrubs, and 0.01% for herbs. On forested plots, we recorded tree basal area and tree density by species for the 0–3 m, 3–10 m, and >10 m height classes.

Data Analysis

Species percent cover was averaged over all plots within a polygon to avoid pseudoreplication. Subsequent statistical analyses were based on the 48 polygons, and not on the 237 individual plots. Rare species, occurring in less than 3 plots, were deleted from the data matrix prior to classification because they act like outliers in multivariate classification algorithms, adding variability that obscures central tendencies (Gauch 1982).

We used TWINSPAN (two-way indicator species analysis) (Hill 1979) to classify samples and species into similar groups. Pseudospecies (a type of differential species based on predetermined abundance levels) cut levels were 0, 2, 5, 10, 20, 35, and 50. Pseudospecies cut levels of 20, 35, and 50 received twice the weighting of the others in order to favor dominants. Plant associations were described using percent cover and constancy.

Species richness was determined for each classified plant association. Richness estimates were based on the cumulative number of species in 5 randomly selected plots from each plant association. We did this to avoid sampling area bias and to ensure comparability between plant associations (Magurran 1988).

Successional Inferences

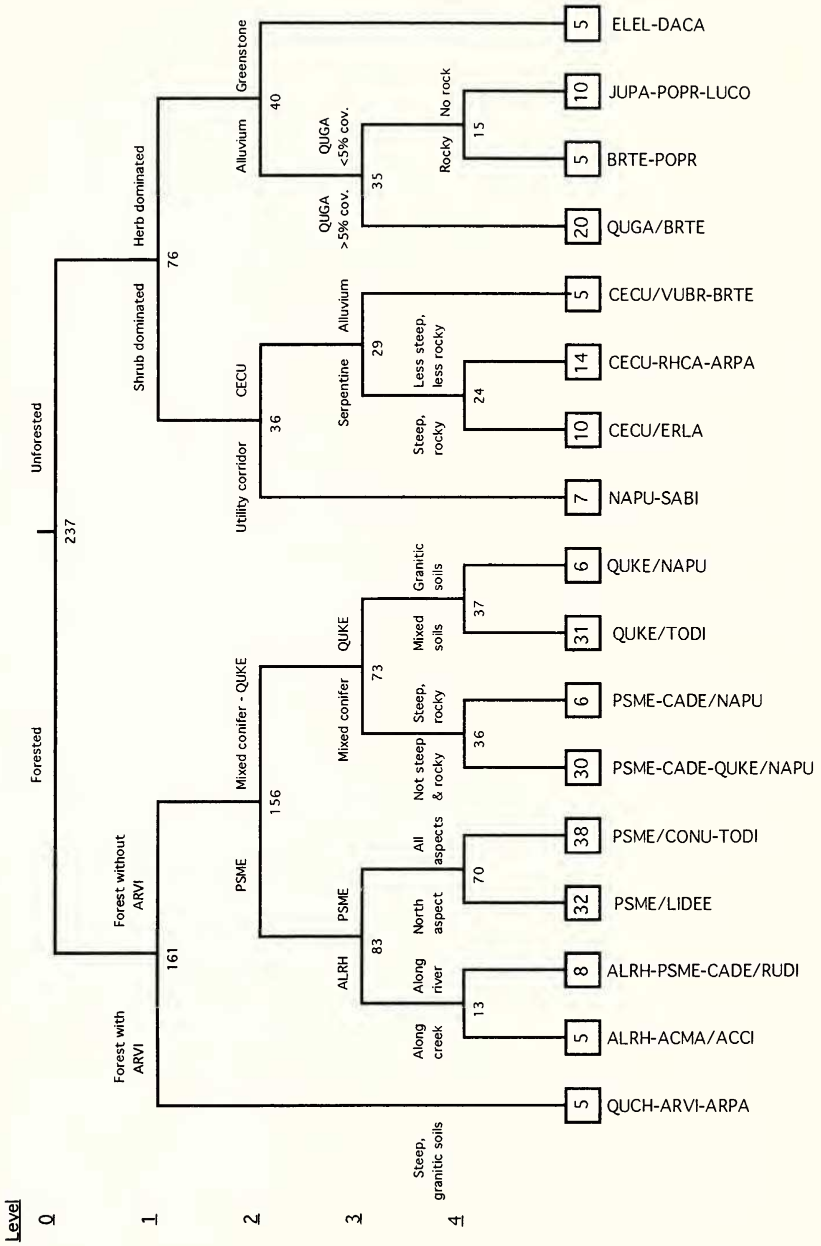
Successional inferences were based on the life history attributes of potential canopy dominants: mode of persistence, species tolerance of understory conditions, fire tolerance, longevity, stature, and reproductive success in the understory.

Results and Discussion

Classification and Description of Plant Associations

We interpreted 8 series and 15 plant associations from the TWINSPAN output (Fig. 1). Nine associations were forested (Table 1); 3 were shrublands (Table 2); and 3 were herb-dominated (Table 3). In addition, two communities occurred in chronically disturbed sites: beneath a powerline, and in a mowed meadow. Level zero in the dendrogram (Fig. 1) divided forested from unforested plots. Level 1 separated plots according to life form, and levels 2 and 3 according to dominant overstory species, physiognomy, or parent material. Level 4 further divided plots according to physiography or parent material.

Physiographic and soil characteristics of each plant association


Level
0
1
2
3
4
237
Unforested
Forested
76
Herb dominated
Shrub dominated
161
Forest without ARVI
Forest with ARVI
40
Greenstone
Alluvium
36
CECU
Utility corridor
156
Mixed conifer - QUKE
PSME
35
QUGA <5% cov.
QUGA >5% cov.
29
Alluvium
Serpentine
73
QUKE
Mixed conifer
83
PSME
ALRH
15
No rock
Rocky
24
Less steep, less rocky
Steep, rocky
37
Granitic soils
Mixed soils
36
Steep, rocky
Not steep & rocky
70
All aspects
North aspect
13
Along river
Along creek
Steep, granitic soils
5 ELEL-DACA
10 JUPA-POPR-LUCO
5 BRTE-POPR
20 QUGA/BRTE
5 CECU/VUBR-BRTE
14 CECU-RHCA-ARPA
10 CECU/ERLA
7 NAPU-SABI
6 QUKE/NAPU
31 QUKE/TODI
6 PSME-CADE/NAPU
30 PSME-CADE-QUKE/NAPU
38 PSME/CONU-TODI
32 PSME/LIDEE
8 ALRH-PSME-CADE/RUDI
5 ALRH-ACMA/ACCI
5 QUCH-ARVI-ARPA

are presented in Table 4. Basal area, species richness, and tree density for each plant association are presented in Table 5.

Pseudotsuga menziesii Series

All plant associations within the *Pseudotsuga menziesii* series had moderately deep soils, gravely loam soil textures, and were found on greenstone, alluvium, or basaltic rock. Differences between *Pseudotsuga menziesii* associations were seen in aspect, % slope, and % rock and bare soil.

1. The *Pseudotsuga menziesii/Lithocarpus densiflorus* var. *echinoides* (PSME/LIDEE) association was dominated by *Pseudotsuga menziesii* with 40% cover and 100% constancy. The shrub form of *Lithocarpus densiflorus,* var. *echinoides,* was dominant in the understory with 24% cover and 94% constancy. Species richness was 27 and there were 39.7 m^2/ha of basal area. This association typically occurred on north aspects. Slopes averaged 27%.
2. *Pseudotsuga menziesii* was predominant in the *Pseudotsuga menziesii/Cornus nuttallii–Toxicodendron diversilobum* (PSME/CONU-TODI) association with 51% cover and 100% constancy. *Calocedrus decurrens* and *Quercus kelloggii* were minor canopy associates. *Cornus nuttallii* and *Toxicodendron diversilobum* had the greatest cover and constancy in the understory. This association had the most biomass (basal area = 57.2 m^2/ha) and the least exposed rock and bare soil. No other

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FIG. 1. Twinspan dendrogram with interpretative annotations. Numbers beneath lines represent the number of plots prior to division. Numbers in boxes are the number of plots in each classified plant association. Labels beneath numbered boxes are plant association acronyms. QUCH/ARVI-ARPA = *Quercus garryana/Arctostaphylos viscida–Arctostaphylos patula,* ALRH-ACMA/ACCI = *Alnus rhombifolia–Acer macrophyllum/Acer circinatum,* ALRH-PSME-CADE/RUDI = *Alnus rhombifolia–Pseudotsuga menziesii–Calocedrus decurrens/Rubus discolor,* PSME/LIDEE = *Pseudotsuga menziesii/Lithocarpus densiflorus* var. *echinoides,* PSME/CONU-TODI = *Pseudotsuga menziesii/Cornus nuttallii–Toxicodendron diversilobum,* PSME-CADE-QUKE/NAPU = *Pseudotsuga menziesii–Calocedrus decurrens–Quercus kelloggii/Nassella pulchra,* PSME-CADE/NAPU = *Pseudotsuga menziesii–Calocedrus decurrens/Nassella pulchra,* QUKE/TODI = *Quercus kelloggii/Toxicodendron diversilobum,* QUKE/NAPU = *Quercus kelloggii/Nassella pulchra,* NAPU-SABI = *Nassella pulchra–Sanicula bipinnatiifida,* CECU/ERLA = *Ceanothus cuneatus/Eriophyllum lanatum,* CECU-RHCA-ARPA = *Ceanothus cuneatus–Rhamnus californica–Arctostaphylos patula,* CECU/VUBR-BRTE = *Ceanothus cuneatus/Vulpia bromoides–Bromus tectorum,* QUGA/BRTE = *Quercus garryana/Bromus tectorum,* BRTE-POPR = *Bromus tectorum–Poa pratensis,* JUPA-POPR-LUCO = *Juncus patens–Poa pratensis–Luzula comosa,* ELEL-DACA = *Elymus elymoides–Danthonia californica.*

TABLE 1. AVERAGE COVER AND CONSTANCY FOR FOREST ASSOCIATIONS. Species reported are those with >50% constancy. [1] See Figure 1 for plant association acronyms. [2] COV = average cover (%). [3] CON = constancy (%).

Plant association[1] (number of plots)	QUCH/ARVI-ARPA (5)		ALRH-ACMA/ACCI (5)		ALRH-PSME-CADE/RUDI (8)	
	COV[2]	CON[3]	COV	CON	COV	CON
Arctostaphylos patula	23	100				
Arctostaphylos viscida	34	100				
Quercus chrysolepis	19	100			2	50
Smilax californica			<1	80		
Rubus ursinus			<1	80		
Rhododendron occidentale			1	80		
Rhamnus purshiana			7	100		
Montia perfoliata			5	100		
Lilium pardalinum			<1	80		
Dicentra formosa			<1	60		
Athyrium filix-femina			<1	80		
Aralia californica			2	100		
Adiantum pedatum			<1	80		
Alnus rhombifolia			40	100	15	100
Acer circinatum			12	100	10	63
Trientalis latifolia			<1	80	2	75
Pteridium aquilinum			<1	60		
Acer macrophyllum			20	80	9	63
Symphoricarpos albus						
Corylus cornuta			1	60	8	63
Rosa gymnocarpa					3	50
Rubus discolor					22	63
Rubus leucodermis					6	50
Fraxinus latifolia					10	88
Equisetum laevigatum					5	50
Danthonia pilosa					7	50
Carex subfusca					4	63
Agropyron spicatum					5	75
Lithrocarpus densiflorus var. *echinoides*						
Cornus nuttallii						
Pseudotsuga menziesii			10	80	13	75
Calocedrus decurrens			1	80	12	88
Quercus kelloggii					6	50
Pinus lambertiana						
Pinus ponderosa					4	63
Toxicodendron diversilobum						
Viola lobata						
Luzula comosa						
Galium aparine						
Clarkia gracilis						
Carex cusickii						
Nassella pulchra						
Rhamnus californica						
Sanicula bipinnatiifida						

TABLE 1. EXTENDED.

PSME/ LIDEE (32)		PSME/ CONU-TODI (38)		QUKE/ TODI (31)		PSME-CADE-QUKE/NAP (30)		QUKE/ NAPU (6)		PSME-CADE/ NAPU (6)	
COV	CON	COV	CON	COV	CON	COV	CON	COV	CON	COV	CON
								2	67	1	33
1	56										
3	63										
9	66										
1	50										
4	63										
2	72										
24	94	2	50								
7	75	5	50								
40	100	51	100	10	94	24	100	2	50	22	100
6	75	11	87	6	65	12	97			21	100
11	84	8	74	32	94	15	83	63	100		
4	56	4	50								
5	59			13	87	6	50	5	67		
			1	61	4	68					
								<1	50		
								1	50		
				<1	52			<1	50		
								<1	50		
								6	67		
								11	67	18	67
								6	50	10	83
										4	67

TABLE 1. CONTINUED.

Plant association[1] (number of plots)	QUCH/ARVI-ARPA (5)		ALRH-ACMA/ACCI (5)		ALRH-PSME-CADE/RUDI (8)	
	COV[2]	CON[3]	COV	CON	COV	CON
Pinus jeffreyi						
Phlox speciosa						
Monardella odoratissima						
Lomatium macrocarpum						
Festuca californica						
Epilobium brachycarpum						
Dichelostemma mulitflorum						
Cheilanthes gracilis						
Ceanothus cuneatus						
Agoseris retrorsa						

association had as many trees taller than 10 m (208/ha). Unlike the north-loving PSME/LIDEE, PSME/CONU-TODI was found on all aspects.

3. The *Pseudotsuga menziesii–Calocedrus decurrens–Quercus kelloggii/Nassella pulchra* (PSME-CADE-QUKE/NAPU) association differed from the first two *Pseudotsuga menziesii* associations in that it had several co-dominant tree species in the canopy. *Pseudotsuga menziesii* was still dominant with 24% cover (100% constancy), followed by *Calocedrus decurrens* with 12% cover (97% constancy), and then by *Quercus kelloggii* with 15% cover (83% constancy). *Nassella pulchra* had the greatest understory cover. This type had more rock and bare soil (6%) than the first two *Pseudotsuga menziesii* types and was found on all aspects. It had the second highest total tree density (756 trees/ha), an average basal area of 35.8 m^2/ha, and species richness of 29.
4. The *Pseudotsuga menziesii–Calocedrus decurrens/Nassella pulchra* (PSME-CADE/NAPU) association resembled PSME-CADE-QUKE/NAPU in dominant species composition, but was found at higher elevations, western aspects, and on steeper (52% versus 26%), rockier slopes (24%). This association had less biomass, with only 25.3 m^2/ha of basal area and 46 trees/ha taller than 10 m. *Pinus jeffreyi* shared the sparse canopy with 9% cover and 67% constancy.

Vegetation dynamics. Pseudotsuga menziesii and *Calocedrus decurrens* were the most abundant reproducing species in PSME/CONU-TODI, PSME-CADE-QUKE/NAPU, AND PSME-CADE/NAPU. *Lithocarpus densiflorus* and *Pseudotsuga menziesii* were

TABLE 1. EXTENDED. CONTINUED.

PSME/ LIDEE (32)		PSME/ CONU-TODI (38)		QUKE/ TODI (31)		PSME-CADE-QUKE/NAP (30)		QUKE/ NAPU (6)		PSME-CADE/ NAPU (6)	
COV	CON	COV	CON	COV	CON	COV	CON	COV	CON	COV	CON
						8	40			9	67
										<1	50
										2	50
										1	67
										10	50
										<1	50
										1	67
										1	50
										9	67
										<1	50

TABLE 2. AVERAGE COVER AND CONSTANCY FOR SHRUB-DOMINATED ASSOCIATIONS. Species reported are those with >50% constancy. [1] See Figure 1 for plant association acronyms. [2] COV = average cover (%). [3] CON = constancy (%).

Plant association[1] (number of plots)	CECU-RHCA-ARPA (14)		CECU/ ERLA (10)		CECU/ VUBR-BRTE (5)		NAPU-SABI (7)	
	Cov[2]	Con[3]	Cov	Con	Cov	Con	Cov	Con
Arctostaphylos patula	10	79						
Hypericum perforatum	1	50						
Pinus jeffreyi	2	79						
Quercus kelloggii	9	64						
Rhamnus californica	13	86						
Calocedrus decurrens			2	60				
Eriophyllum lanatum			2	90				
Monardella odoratissima			2	70				
Elymus elymoides			2	60				
Ceanothus cuneatus	39	100	22	90	10	60		
Bromus mollis					1	80		
Bromus tectorum					4	80		
Draba verna					<1	80		
Epilobium brachycarpum					<1	100		
Gnaphalium sp.					1	80		
Rumex acetosella					1	60		
Scleranthus annuus					2	80		
Vulpia bromoides					6	80		
Dichelostemma mulitflorum					1	60	1	57
Nassella pulchra	1	100	8	50			22	100
Agoseris retrorsa							1	71
Eriogonum umbellatum							1	71
Sanicula bipinnatiifida	1	57					7	100

TABLE 3. AVERAGE COVER AND CONSTANCY FOR HERB-DOMINATED ASSOCIATIONS. Species reported are those with >50% constancy. [1] See Figure 1 for plant association acronyms. [2] COV = average cover (%). [3] CON = constancy (%).

Plant association[1] (number of plots)	JUPA-POPR-LUCO (10)		BRTE-POPR (5)		QUGA/BRTE (20)		ELEL-DACA (5)	
	COV[2]	CON[3]	COV	CON	COV	CON	COV	CON
Luzula comosa	12	60						
Juncus patens	22	80						
Rubus discolor	5	60						
Nassella pulchra	7	60						
Poa pratensis	12	70	13	60				
Dactylis glomerata			1	60				
Vulpia bromoides			3	60				
Aria caryophyllea					2	55		
Bromus tectorum			15	100	12	90		
Clarkia gracilis					<1	55		
Lupinus argenteus					1	55		
Quercus garryana					10	50		
Rumex acetosella			1	60	1	50		
Scleranthus annuus					2	50		
Danthonia californica							18	80
Lotus humistratus							4	100
Plantago lanceolata							10	80
Ranunculus occidentalis							<1	60
Elymus elymoides							21	80
Tragopogon dubius							<1	60
Trifolium macraei							3	60
Triteleia hyacinthina							7	60
Verbascum blattaria							<1	60

most abundant in PSME/LIDEE. These species were more shade tolerant than other associated tree species (Franklin and Dryness 1973; Powers and Oliver 1990) and, in the absence of fire or other disturbance, should become self-perpetuating (McDonald 1980; Sawyer 1980; Hermann and Lavender 1990). With fire, *Pinus ponderosa, Quercus kelloggii,* and *Pinus lambertiana* should remain within the mix of overstory dominants and co-dominants (Franklin and Dryness 1973, and Sawyer et al. 1977).

Relation to other vegetation types. PSME/CONU-TODI, PSME-CADE-QUKE/NAPU, and PSME-CADE/NAPU share elements of the warm, dry component of the mixed conifer forests found in southwestern Oregon (Franklin and Dryness 1973); of the mesic, low elevation type in the Sierra Nevada/Cascade mixed conifer forest (Rundel et al. 1977; Holland 1986); and of the Pacific ponderosa pine–Douglas-fir cover type (McDonald 1980). A *Pseudotsuga menziesii–Calocedrus decurrens* type has been described in southern

TABLE 4. PHYSIOGRAPHIC AND SOIL CHARACTERISTICS OF CASTLE CRAGS PLANT ASSOCIATIONS. Data are averages of plots within a plant association. [1] See Figure 1 for plant association acronyms.

Plant associations[1]	Elevation (m)	Predominant aspect	Slope (%)	% rock and bare soil	Predominant parent material	Predominant soil depth (m)	Predominant soil texture
QUCH/ARVI-ARPA	927	S	69	15	Granite	0.3–0.5	Coarse sandy loam
ALRH-ACMA/ACCI	751	E	14	32	Alluvium	>1.5	Cobbly sandy loam
ALRH-PSME-CADE/RUDI	640	S	1	6	Alluvium	>1.5	Cobbly sandy loam
PSME/LIDEE	803	N	27	3	Greenstone	1.0–2.0	Gravelly loam
PSME/CONU-TODI	730	ALL	39	1	Greenstone, alluvium	>1.0	Gravelly loam
PSME-CADE-QUKE/NAPU	800	ALL	26	6	Greenstone, alluvium, basaltic rock	1.0–2.0	Gravelly loam
PSME-CADE/NAPU	968	W	52	24	Greenstone, alluvium, basaltic rock	1.0–1.8	Gravelly loam
QUKE/TODI	835	S	47	3	Greenstone, alluvium, basaltic rock	1.0–2.0	Gravelly loam
QUKE/NAPU	753	S	23	1	Granite	0.3–0.5	Coarse sandy loam
NAPU-SABI	735	ALL	23	26	Greenstone	1.0–2.0	Gravelly loam
CECU/ERLA	920	S	47	28	Serpentine, greenstone	0.5–1.0	Stony loam
CECU-RHCA-ARPA	762	S	42	20	Serpentine	0.5–0.76	Stony loam
CECU/VUBR-BRTE	680	S	2	23	Alluvium	>1.5	Cobbly sandy loam
QUGA/BRTE	666	FLAT	1	31	Alluvium	>1.5	Cobbly sandy loam
BRTE-POPR	658	FLAT	0	40	Alluvium	>1.5	Cobbly sandy loam
JUPA-POPR-LUCO	658	FLAT	1	0	Alluvium	>1.5	Cobbly sandy loam
ELEL-DACA	619	E	8	1	Greenstone	1.0–2.0	Gravelly loam

TABLE 5. BASAL AREA, CUMULATIVE NUMBER OF SPECIES PER 5 RANDOMLY SELECTED PLOTS, TOTAL NUMBER OF SPECIES IN ALL PLOTS, AND TREE DENSITY FOR EACH PLANT ASSOCIATION. [1] See Figure 1 for plant associations acronyms.

Plant association[1]	Basal area (m^2/ha)	# species/ 5 plots	Total # of species in all plots	Tree density by height class (#/ha)			
				0–3 m	3–10 m	>10 m	Total
QUCH/ARVI-ARPA	2.3	9	9	22	20	0	42
					0		
ALRH-ACMA/ACCI	—[2]	37	37	0		0	0
ALRH-PSME-CADE/RUDI	47.6	70	86	250	75	91	416
PSME/LIDEE	39.7	42	76	634	191	143	968
PSME/CONU-TODI	57.2	33	53	179	95	208	482
PSME-CADE-QUKE/NAPU	35.8	29	90	462	165	129	756
PSME-CADE/NAPU	25.3	32	37	136	62	46	244
QUKE/TODI	40.2	37	76	377	257	60	694
QUKE/NAPU	6.3	31	36	282	213	88	583
NAPU-SABI	0	56	68	0	0	0	0
CECU/ERLA	3.7	39	45	11	7	2	20
CECU-RHCA-ARPA	0.8	43	56	9	7	1	17
CECU/VUBR-BRTE	0	40	40	14	4	0	18
QUGA/BRTE	1	38	81	14	6	11	31
BRTE-POPR	0.5	19	19	0	0	2	2
JUPA-POPR-LUCO	0.9	28	42	14	6	0	20
ELEL-DACA	0	37	37	0	0	0	0

[2] Missing data.

Oregon by Mitchell and Moir (1976). A PSME/CONU type is found in the Cub Creek Research Natural Area in the Lassen National Forest (Taylor and Randall 1990). PSME/LIDEE is similar to the *Pseudotsuga/Lithocarpus* (shrub form) phase in the *Pseudotsuga* hardwood forest of the Klamath Mountains (Sawyer et al. 1977). *Lithocarpus densiflorus* var. *echinoides* grows in a narrow elevational band above the tree form of *L. densiflorus* on moist sites in the eastern Klamath Mountain Province (Tappeiner et al. 1990).

Quercus kelloggii Series

1. The *Quercus kelloggii/Toxicodendron diversilobum* (QUKE/TODI) association was dominated by *Quercus kelloggii* with 32% cover (94% constancy). Minor canopy associates included *Pseudotsuga menziesii* with 10% cover (94% constancy) and *Pinus ponderosa* with 13% cover (87% constancy). *Toxicodendron diversilobum* had 4% cover and 68% constancy. The 40.2 m^2/ha of basal area was relatively high. Most of the 634 trees/ha shorter than 10 m tall were *Pseudotsuga menziesii, Calocedrus decurrens,* or some other late seral species. This association was found primarily on south aspects with slopes averaging 47%. Soil depths were between 1 and 2 m, having originated from either greenstone, alluvium, or basaltic rock.
2. Granitic parent material and shallow soils differentiate the *Quercus kelloggii/Nassella pulchra* (QUKE/NAPU) association from QUKE/TODI. This type was overwhelmingly dominated by *Quercus kelloggii,* having 63% cover and 100% constancy. *Pinus ponderosa* and *Pseudotsuga menziesii* were occasional canopy associates. The most abundant understory species were *Nassella pulchra, Carex cusikii,* and *Rhamnus californica.* Basal area was about 1/7th that found in QUKE/TODI.

Vegetation dynamics. Pseudotsuga menziesii and *Calocedrus decurrens* were the most abundant reproducing species in QUKE/TODI. This association is seral and will eventually be dominated by *Pseudotsuga menziesii* and *Calocedrus decurrens* (McDonald 1990). In the Sierra Nevada/Cascade mixed conifer forest, *Quercus kelloggii* is well adapted to light, regular surface fires and often will be succeeded by *Calocedrus decurrens* in the absence of fire (Rundel et al. 1977; McDonald 1990). QUKE/NAPU represents a self-perpetuating vegetation type largely because of the xeric conditions produced from steep, shallow, granitic soils. *Quercus kelloggii* is very drought resistant and can grow on sites too poor for other mixed conifer species (Rundel et al. 1977; McDonald 1990).

Relation to other vegetation types. Quercus kelloggii forests and woodlands have been reported as occurring on fire-prone, dry, warm sites throughout southwestern Oregon (Whittaker 1960; Waring 1969) and in the northern Sierra Nevada and Cascade Mountains of California (Holland 1986; McDonald 1990). QUKE/TODI vegetation types have been described by Keeler-Wolf (1990a).

Alnus rhombifolia Series

1. The *Alnus rhombifolia–Pseudotsuga menziesii–Calocderus decurrens/Rubus discolor* (ALRH-PSME-CADE/RUDI) association was found on alluvial soils along either the Sacramento River or Castle Creek. *Alnus rhombifolia* was the most common canopy species, having 15% cover (100% constancy). *Pseudotsuga menziesii* had 13% cover (75% constancy) and *Calocedrus decurrens* had 12% cover (88% constancy). *Rubus discolor* dominated the understory, having 22% cover and 63% constancy. ALRH-PSME-CADE/RUDI was structurally and floristically complex. This association had the greatest species richness (70 species) and the second highest basal area (47.6 m^2/ha).
2. The *Alnus rhombifolia–Acer macrophyllum/Acer circinatum* (ALRH-ACMA/ACCI) association occurred along smaller streams like Root Creek or Indian Creek. These riparian zones typically had more shade, were cooler, and had lower species richness (37 species) than ALRH-PSME-CADE/RUDI.

Vegetation dynamics. Both ALRH-PSME-CADE/RUDI and ALRH-ACMA/ACCI are self-perpetuating. Flooding and fire are the primary disturbances expected in these types. Fire severity, though, would usually be less than surrounding upland slopes because of higher fuel moisture contents, higher relative humidities, and lower temperatures.

Relation to other vegetation types. Our riparian associations are generally similar to the white alder-dominated communities south of the Willamette Valley in Oregon (Franklin and Dryness 1973) and those scattered throughout the Klamath, northern Sierra Nevada, and Cascade Mountains. Keeler-Wolf (1990a) described a canyon riparian forest that is similar to our ALRH-ACMA/ACCI.

Quercus chrysolepis Series

The *Quercus chrysolepis/Arctostaphylos viscida–A. patula* (QUCH/ARVI-ARPA) association was the most depauperate and unproductive of all forest associations in the park. It had only 9 species and 2.3 m^2/ha of basal area. *Quercus chrysolepis* was the dominant tree with 19% cover and 100% constancy. Manzanita dominated the understory. *Arctostaphylos viscida* had 34% cover

(100% constancy) and *Arctostaphylos patula* had 23% cover (100% constancy). This type was found on shallow, granitic soils on steep, south aspects in the Castle Creek Valley.

Vegetation dynamics. Quercus chrysolepis is climax on very steep, colluvial soils (Thornburgh 1990). When subjected to repeated fire, a *Quercus chrysolepis* chaparral type develops. With fire suppression, the chaparral should eventually revert back to a *Quercus chrysolepis*-dominated association (Mallory 1980).

Relation to other vegetation types QUCH/ARVI-ARPA is generally similar to the *Quercus chrysolepis–Pseudotsuga menziesii*-dominated forests found on very steep, colluvial soils throughout the Klamath Mountains Province (Mallory 1980; Thornburgh 1990). Our type, however, lacks *Pseudotsuga menziesii* and has a distinctive *Arctostaphylos* understory similar in composition to montane chaparral described by Hanes (1977). Horton (1960) described a *Q. chrysolepis-Arctostaphylos* spp. phase of the live oak (*Q. wislizenii*) chaparral found in the San Bernadino Mountains.

Ceanothus cuneatus Series

Ceanothus cuneatus associations were all found in Castle Creek Valley on south aspects and either on serpentine, greenstone, or alluvial soils. Serpentine soils were shallow, steep, xeric, and infertile.

1. The *Ceanothus cuneatus–Rhamnus californica–Arctostaphylos patula* (CECU-RHCA-ARPA) association was found on serpentine soils. Shrubs accounted for 62% relative cover, herbs had 24%, and trees 14%. Trees were scattered throughout the type, but species constancy was typically low. Although *Pinus jeffreyi* had the greatest tree cover, basal area was only 0.8 m^2/ha and there was only 1 tree/ha taller than 10 m. *Ceanothus cuneatus* had 39% cover (100% constancy), *Rhamnus californica* had 13% cover (86% constancy), and *Arctostaphylos patula* had 10% cover (79% constancy).
2. The *Ceanothus cuneatus/Eriophyllum lanatum* (CECU/ERLA) association was found on serpentine and greenstone. This type had rockier soils, steeper slopes, and more herb cover than CECU-RHCA-ARPA. Shrub relative cover was 45%, herbs 42%, and trees 13%. *Nassella pulchra* had more cover than *Eriophyllum lanatum* (8% versus 2%), but had lower constancy (50% versus 90%). *Calocedrus decurrens* was widely scattered, having 3.7 m^2/ha of basal area and only 2 trees/ha taller than 10 m. *Ceanothus cuneatus* dominated with 22% cover and 90% constancy.
3. The *Ceanothus cuneatus/Vulpia bromoides–Bromus tectorum* (CECU/VUBR-BRTE) association was found on gravely, cob-

bly alluvium. Herb relative cover was 58%, shrub relative cover 35%, and tree relative cover 7%. While this type had about the same species richness (40) as CECU-RHCA-ARPA (43) or CECU/ERLA (39), it had much less cover. There was only 10% *Ceanothus cuneatus* cover (60% constancy), 6% *Vulpia bromoides* cover (80% constancy), and 4% *Bromus tectorum* cover (80% constancy). There were no trees taller than 10m and no basal area.

Vegetation dynamics. CECU-RHCA-ARPA and CECU/ERLA are self-perpetuating on xeric, serpentinitic, steep slopes. CECU/VUBR-BRTE is probably self-perpetuating. Although it grows on alluvium, the soil is xeric, having been derived from a melange of coarse-textured granitic and ultramafic rocks. In the absence of fire, *Calocedrus decurrens* should increase in abundance, but should not dominate these harsh sites. With fire, *Ceanothus cuneatus* should increase in abundance.

Relation to other vegetation types. Our *Ceanothus cuneatus* associations resemble Holland's (1986) buck brush chaparral, Hane's (1977) serpentine chaparral in California, and serpentine chaparrals occurring between 860 to 980 m in the Siskiyou Mountains of southwestern Oregon (Franklin and Dryness 1973). Taylor and Teare (1990) listed a *Ceanothus cuneatus/Sitanion hystrix* association in Trinity County and Keeler-Wolf (1990b) described a *Ceanothus* scrub type in Tehama County.

Bromus tectorum series

The *Bromus tectorum–Poa pratensis* (BRTE-POPR) association was found on very cobbly alluvium in the Castle Creek Valley. The type is relatively depauperate, having 19 species and 40% rock and bare soil. *Bromus tectorum* had 12% cover (90% constancy) and *Poa pratensis* had 10% cover (50% constancy). *Quercus garryana* was scattered throughout the type and had 9% cover but only 20% constancy. Basal area was 0.5 m^2/ha.

Vegetation dynamics. The BRTE-POPR association is an early seral stage in a yet to be determined sere. This type will probably be stable for many decades, however, because of slow soil development.

Relation to other vegetation types. This type would be similar to many other early vegetation communities dominated by *Bromus tectorum* throughout the west (Young 1994, Billings 1994).

Quercus garryana Series

The *Quercus garryana/Bromus tectorum* (QUGA/BRTE) association was found on flat, cobbly, alluvial soils in Castle Creek Valley.

These sites were generally similar to BRTE-POPR sites, excepting for the higher frequency and cover of *Quercus garryana,* fewer cobbles, and less bare soil that characterized QUGA/BRTE. This type had 12% cover of *Bromus tectorum* (90% constancy) and 10% cover of *Quercus garryana* (50% constancy). Species richness was twice (38) that found in BRTE-POPR. Basal area was 1.0 m^2/ha and there were 11 trees/ha taller than 10 m.

Vegetation dynamics. QUGA/BRTE represents an edaphically stable plant association in Castle Crags State Park. Soil development rates on the cobbly alluvium are too slow for this woodland to succeed to another type in the foreseeable future. In some *Quercus garryana* types in northern California and southern Oregon, *Pseudotsuga menziesii* eventually overtops *Q. garryana* in the absence of recurring fire (Agee 1993).

Relation to other vegetation types. QUGA/BRTE is most similar to *Quercus garryana* communities growing on the driest sites in southern Oregon (Whittaker 1960; Riegel et al. 1992) and northern California (Griffin 1977).

Juncus patens Series

This association, *Juncus patens–Poa prataensis–Luzula comosa* (JUPA-POPR-LUCO), was found on seasonally moist soils near a pond in Castle Creek Valley. *Juncus patens* had 22% cover (80% constancy); *Poa pratensis* had 12% cover (70% constancy); and *Luzula comosa* had 12% cover (60% constancy). There were no trees taller than 10m and species richness was 28.

Vegetation dynamics We expect that the high water table on this site will perpetuate JUPA-POPR-LUCO. Other potential dominant species are intolerant of seasonally hydric soils.

Disturbed Communities

Two disturbed communities were classified: *Nassella pulchra–Sanicula bipinnatiifida* (NAPU-SABI) and *Elymus elymoides–Danthonia californica* (ELEL-DACA). NAPU-SABI was found beneath the powerline corridor which transects the park in an approximately N–S orientation. It was dominated by *Nassella pulchra,* which had 22% cover and 100% constancy. Numerous shrubs and tree seedlings were present. ELEL-DACA was a mowed meadow near the campground. It was dominated by *Elymus elymoides* with 21% cover (80% constancy) and by *Danthonia californica* with 18% cover (80% constancy).

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LITERATURE CITED

AGEE, J. K. 1993. Fire ecology of Pacific Northwest Forests. Island Press, Washington, DC. 493 p.

BEAT, W. R. and V. GUT. 1981. The history of Castle Crags and surrounding area. Internal report on file at Castle Crags State Park headquarters, Castella, CA.

BILLINGS, W. D. 1994. Ecological impacts of cheatgrass and resultant fire on ecosystems in the western Great Basin. Pp. 22–30 *in* S. B. Monsen and S. G. Kitchen (eds.), Proceedings—Ecology and management of annual rangelands. U.S.D.A. Forest Service General Technical Report INT-GTR-313.

EYRE, F. H. 1980. Forest cover types of the United States and Canada. Society of American Foresters. Washington, DC. 148 p.

FRANKLIN, J. F. and C. T. DRYNESS. 1973. Natural vegetation of Oregon and Washington. U.S.D.A. Forest Service General Technical Report PNW-8.

GAUCH, H. G. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge, UK. 298 p.

GRIFFIN, J. R. 1977. Oak woodland. Pp. 383–415 *in* M. G. Barbour and J. Major (eds.), Terrestrial vegetation of California. John Wiley and Sons, NY.

HANES, T. L. 1977. California chaparral. Pp. 417–469 *in* M. G. Barbour and J. Major (eds.), Terrestrial vegetation of California. John Wiley and Sons, NY.

HERMANN, R. K. and D. P. LAVENDER. 1990. *Pseudotsuga menziesii* (Mirb.) Franco. Pp. 527–540 *in* Silvics of North America, Vol. 1, Conifers. USDA Forest Service Agricultural Handbook 654.

HILL, M. O. 1979. TWINSPAN—a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and their attributes. Cornell University, Department of Ecology and Systematics, Ithaca, NY.

HOLLAND, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. Unpublished report on file at California Department of Fish and Game, Sacramento, CA. 156 p.

HORTON, J. S. 1960. Vegetation types of the San Bernadino Mountains, California. U.S.D.A. Forest Service Technical Paper #44.

KEELER-WOLF, T. 1990a. Hosselkus Limestone. Pp. 25–28 *in* T. Keeler-Wolf (ed.), Ecological surveys of Forest Service Research Natural Areas in California. U.S.D.A. Forest Service General Technical Report PSW-125.

KEELER-WOLF, T. 1990b. Indian Creek. Pp. 58–61 *in* T. Keeler-Wolf (ed.), Ecological surveys of Forest Service Research Natural Areas in California. U.S.D.A. Forest Service, General Technical Report, PSW-125.

MAGURRAN, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, NJ. 179 p.

MALLORY, J. I. and W. R. POWELL. 1978. Tables for the soil-vegetation map: northeast quarter of the Dunsmuir Quadrangle (14C-1). Siskiyou and Shasta Counties, California. Soil-vegetation survey. Pacific Southwest Forest and Range Experiment Station.

MALLORY, J. I. 1980. Canyon live oak. Pp. 125–126 *in* F. H. Eyre (ed.), Forest cover types of the United States and Canada. Society of American Foresters. Washington, DC. 148 p.

MCDONALD, P. M. 1980. Pacific ponderosa pine–Douglas-fir. P. 120 *in* F. H. Eyre (ed.), Forest cover types of the United States and Canada. Society American Foresters. Washington, DC. 148 p.

McDonald, P. M. 1990. *Quercus kelloggii* Newb. Pp. 661–671 *in* Silvics of North America, Vol. 2, Hardwoods. U.S.D.A. Forest Service Agricultural Handbook 654.

Mitchell, R. and W. Moir. 1976. Vegetation of the Abbott Creek Research Natural Area, Oregon. Northwest Science 50(1):42–58.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, NY. 547 p.

National Climatic Data Center. 1990. Climatological data, California, Jan.-Dec. 1990. Vol. 94. NOAA.

Powers, R. F. and W. W. Oliver. 1990. *Libocedrus decurrens* Torr. Pp. 173–180 *in* Silvics of North America, Vol. 1, Conifers. U.S.D.A. Forest Service Agricultural Handbook 654.

Riegel, G. M., B. G. Smith, and J. F. Franklin. 1992. Foothill oak woodlands of the interior valleys of southwestern Oregon. Northwest Science 66:66–76.

Rundel, P. W., D. J. Parsons, and D. T. Gordon. 1977. Montane and subalpine vegetation of the Sierra Nevada and Cascade Ranges. Pp. 559–599 *in* M. B. Barbour and J Major (eds.), Terrestrial vegetation of California. John Wiley and Sons, NY.

Sawyer, J. O. 1980. Douglas-fir - tanoak - Pacific madrone. Pp. 111–112 *in* F. H. Eyre (ed.), Forest cover types of the United States and Canada. Society of American Foresters. Washington, DC.

Sawyer, J. O, D. A. Thornburgh, and J. R. Griffin. 1977. Mixed evergreen forest. Pp. 359–381 *in* M. G. Barbour and J. Major (eds.), Terrestrial vegetation of California. John Wiley and Sons, NY.

Tappeiner, J. C., P. M. McDonald, and D. F. Roy. 1990. *Lithocarpus densiflorus* (Hook. & Arn.) Rehd. Pp. 417–425 *in* Silvics of North America, Vol. 2, Hardwoods. U.S.D.A. Forest Service Agricultural Handbook 654.

Taylor, D. W. and D. C. Randall. 1978. Cub Creek. Pp. 57–58 *in* T. Keeler-Wolf (ed.), Ecological surveys of Forest Service Research Natural Areas in California. U.S.D.A. Forest Service General Technical Report, PSW-125.

Taylor, D. W. and K. A. Teare. 1990. Smoky Creek. Pp. 41–42 *in* T. Keeler-Wolf (ed.), Ecological surveys of Forest Service Research Natural Areas in California. U.S.D.A. Forest Service, General Technical Report, PSW-125.

Thornburgh. D. A. 1990. *Quercus chrysolepis* Liebm. Pp. 618–624 *in* Silvics of North America, Vol. 2, Hardwoods. U.S.D.A. Forest Service Agricultural Handbook 654.

Waring, R. H. 1969. Forest plants of the eastern Siskiyous: their environmental and vegetational distribution. Northwest Science 43(1):1–17.

Whittaker, R. H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30(3):279–338.

Young, J. A. 1994. History and use of semiarid plant communities—changes in vegetation. Pp. 5–8 *in* S. B. Monsen and S. G. Kitchen (eds.), Proceedings—Ecology and management of annual rangelands. U.S.D.A. Forest Service General Technical Report, INT-GTR-313.

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